body's velocity. In this last case we have stuck to one point of view and obtained a correct result.

This feature connected with the so-called "addition of velocities" is what Professor Michelson and others so strongly object to in the relativity principle, but the result is a perfectly natural one as soon as we have seen the admissibility of more than one point of view and the difference in estimates caused thereby.

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SOME CONSIDERATIONS AS TO THE NATURE OF COMETS AND THEIR PROBABLE RELATION TO THE SUN

THE ideas herein put forward are not all original with the author, though it is believed some of them may be. It is hoped that the considerations may, however, help to a simple rational understanding of the major facts regarding the behavior of comets.

The exceedingly high temperature of the sun causes it to be surrounded by an atmosphere of vapors. Some of the vaporized matter condenses in the outermost layers and eruptions are constantly occurring which partly fill the space around it with very fine particles, the smaller of which are repelled by the pressure of the sun's radiation, which pressure even overcomes the gravitative force of the sun itself. These ejected particles probably constitute the streamers which are visible during total èclipses as extending from the sun to immense distances. What we see is the effect of innumerable overlapping streams. Their extreme tenuity is evidenced by the comparatively feeble luminosity in spite of the great depth of the flux which we are at any time observing. This depth is, of course, greater than the diameter of the sun. Such coronal streamers are by no means uniformly distributed about the sun, but in certain directions, varying continually, may be more dense than in others, coinciding perhaps with great eruptive areas of the sun's surface. It probably happens that when the outbreak is unusually violent, and when the earth happens to be passing through that part of space occupied by an abnormally extended streamer, an aurora of greater or less intensity or duration may attend the sweeping of the earth by such a streamer. The particles are probably ions or carry electric charges, and induced auroral streamers in the earth's atmosphere are for the time being visible on its dark side away from the sun.

It has been thought that comets may act in a somewhat similar way to disclose the condition of the ejected material of the sun, or, as may be conceived, to disclose a stratification or unevenness of distribution of the ejected matter from the sun. Since there is reason to believe that much of this matter is in a highly electrified state, it is not to be doubted that electrical phenomena are at the same time produced, with accompanying evolution of light. Indeed, in the free space around the sun, there must be a great intensity of ultra-violet radiation which of itself would cause emission of negative ions from matter in its path and produce electrical disturbances. But aside from this possibility, the comet is recognized as an assemblage of particles larger or smaller, moving in an orbit which involves great variations of its distance from the sun. In passing through the depths of space far away from the sun, these parts or particles may tend, by their very feeble gravitative effect, to gather up any finer particles which, on account of the intense cold of space, are substantially solid, even though at ordinary temperatures they would be gaseous. The parts of the comet's nucleus more or less porous would in this way accumulate upon their surfaces and in their pores occluded gases, condensed material and fine dust, and there would be a period of many years in which this gathering-up process, as in the case of Donati's and other long-period comets, could occur. Let a comet as an assemblage of such small masses after its long course through remote space, during which it has gathered fine particles ejected from the sun or from other bodies, reach, in

approaching the sun, a part of its orbit where the temperature given by the solar radiation to the surfaces of the masses is sufficient to boil off or regasify the condensed material; then not only is the gas blown off into vacuous space around the nucleus of the comet, but it is naturally blown off in the direction towards the sun, from the heated side of each mass, and at the same time that the gas leaves the mass other fine particles are lifted by the force of the escaping gas. This is due to the fact that these fine or dust-like particles are not held with any strong gravitative tendency. Ultra-violet radiation may also add its effect in causing discharge of negative ions. The result of this is that jets or flows of materials from the nucleus tend into the vacuum towards the sun from the warmed or radiation absorbing surfaces of the comet's nuclear masses. As soon as they leave the nucleus or the warmed surfaces, they are again cold and mainly condensed. But, though exceedingly fine, they are now absorbers, more or less solid, of the sun's radiation, and are gradually thrust backward by the pressure of the light and radiation and are blown off in the opposite direction by this pressure, so forming a tail in the contrary direction from the sun, or in a direction opposite to that in which they were first ejected. There being in matter all grades of volatility, as the cometary body approaches the sun, material more and more refractory, so to speak, would be evolved, until finally, if the approach is near enough to the sun, even ordinarily solid substances would be vaporized from the nuclear masses and projected to form a tail, as has just been described. Some of this vaporized matter would immediately condense on getting a little farther away, and form solid particles in the tail. The comet of January, 1910, showed sodium lines, showing that the temperature of the nuclear masses had probably reached the vaporization point of sodium. The greatest extension of a comet's tail usually comes just after the comet passes perihelion, because the heating process keeps on, as it were, a little past perihelion, just as the hottest part of our summer days is two or three o'clock in the afternoon. Now if the comet stays in proximity to the sun long enough, it will have discharged nearly all of its volatile material for a particular temperature reached. But on leaving the sun after the tail has shrunk (which is a very natural thing for it to do when the body passes through regions less heated by solar rays), it may again be in the condition to gather up the condensed and practically solid gases and vapors in the space around it. And if its period is a long one, such as 2,000 years, as in the case of Donati's comet, it should not surprise us if there is sufficient material to form a fair tail, which only lasts a few weeks at the most. Then it must be borne in mind, too, that an extremely small amount of material diffused in space under solar radiation will suffice to form a very large tail, as every particle, even of extremely small mass, becomes substantially a light source. Take, for instance, the amount of tobacco smoke that can cloud up a room when the sun is shining in it, and it will be found to be a very small quantity, but, if the room be black as night and a hole be made in a shutter through which a small beam of sunlight enters and the minutest body of smoke be diffused in the room, there will be a "comet's tail" extending from the opening across the room where the sunbeam passes because it will be seen in blackness and that is the condition of our seeing comets' tails; in the darkness of night. Then we must remember how deep the space is which is occupied as a visible thickness in a comet's tail, say, 50,000 miles. We thus get an idea of how *free* of particles space must be *not* to shine with a luminosity equal to that of a comet's tail when we look off into the dark night irradiated by the intense solar beams.

Doubtless the simple view here given is complicated by many other actions, electric, etc. Comet's tails sometimes vary greatly and rapidly. We need not be surprised at this when boiling points are known to be critical; when, in other words, a few degrees increase in temperature may vaporize a substance

which would not otherwise have been vaporized. Furthermore, it is quite possible that the comet, in moving around the sun, entangles itself in the stream of material driven from the sun and varies in its effects in accordance with its being or not being in a solar streamer more or less dense for the time being, speaking relatively. It is easily conceivable that an assumed stratification of space may be a cause of variations of comet's tail brightness. Putting it more properly, it is conceivable that a comet may act as an indicator of the condition of space around the sun, the space in which the comet, for the time being, is moving. Even under the idea that there is volatile matter emitted from the sun which ordinarily would not be visible, let such matter strike into the nucleus of a comet and meet matter from the comet itself; it is easily seen that interactions, electrical or otherwise, or even physical collisions, may add to the light of a comet's tail.

The chief point, however, which I have endeavored to emphasize by the comparisons above made, is the excessive tenuity of the matter which would be sufficient to give rise to a brilliant appendage to a comet and the exceedingly small amount of volatile matter needed. This fact renders it possible that the comet may, in the lapse of many years, replenish itself in the depths of space and may account for the fact that at each return, even to close proximity to the sun, a tail is developed. Otherwise, since the matter of the tail certainly does not return to the comet, it would seem that the volatile matter would be distilled off and lost in a very few perihelion passages.

ELIHU THOMSON

ROBERT PARR WHITFIELD

PROFESSOR ROBERT PARR WHITFIELD died on April 6 at Troy, N. Y., in his eighty-second year.

Professor Whitfield's association with the progress of paleontological science in the United States has placed his name permanently among the pioneers of that science in this country. His work, however, has no antiquarian interest merely. From the first it was forcible, careful and convincing. Throughout the long period of his connection with the American Museum of Natural History he industriously contributed papers on invertebrate paleontology, to the publications of that institution, while his work on the surveys of Ohio, Wisconsin and New Jersey was persistently prosecuted, in reports of great value, distinguished always by keen morphological discrimination.

His work began with his employment on the New York State Survey, where he assisted Professor James Hall, who was then engaged in his studies of Paleozoic fossils. Professor Whitfield's assistance was at first in the nature of exact preparatory analyses of the copious material offered for examination, classification and description. About this time he produced the beautiful illustrations of graptolites which gave distinction and an unusual interest to the decades of the Canadian Survey, and his painfully minute study upon which superinduced a, fortunately, only momentary, danger to his eyesight. He continued his labors on the survey until 1877, and helped materially to give precision and a broad zoological basis of comparison to the reconstructions of the invertebrate life of the past, in the papers and volumes, written by Professor Hall, not only upon the paleontology of New York, but of western states as well. His studies of the internal loops of various genera of brachiopoda, his delineation of the muscular scars of lingula and his rearrangement of the crinoidal scheme of plates were all very helpful. Succeeding this came his admirable descriptive papers published in the geological reports of Wisconsin and Ohio. Then followed an exhaustive examination of the upper Devonian lamellibranchs, the results of which were embodied in the subsequent New York survey volumes on these shells.

When the great Hall collection of fossils came into the possession of the American Museum, Professor Whitfield was invited to take charge of this extraordinary cabinet, to